# A tool for measuring sustainability of cities. Case study on Eastern European states

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**Abstract:** The objective of our research was to design a tool for analyzing the progress made on the way to a sustainable urban development, that can be applied and tested at different levels. In the research we carried out, it was started from the study of the various existing tools at the world and European level regarding the analysis of sustainability and of relevant indicators in the context of urban sustainability. Based on them, we designed our own system of indicators - components of a composite index that gave us the opportunity to compare and make a ranking between the European states that we analyzed from the point of view of the indicators taken into account. We carried out the sustainability assessment with the help of a composite indicator resulting from the assessment of 3 key areas: economic, environmental and social, each area being divided into several categories, each category including a certain number of indicators. A very important criterion regarding the choice of indicators was the availability of their values, which led us to perform the analysis at the level of the 11 chosen European states. The reasoning behind the calculation of the composite indicator was based on the use of the AHP method to determine the importance coefficients associated with each indicator. A group of 3 experts analyzed each key domain, subdomain and group of indicators, to establish the relative importance of the subdomains, the groups of indicators in each subdomain, and the indicators in each group.In the future, we propose to expand our research, using the tool designed by us and to identify those indicators that best reflect the needs and objectives of the cities in Romania in order to compare them in terms of sustainable urban development and to support local authorities with ideas and solutions in this direction.

Keywords: Composite index, sustainable development indicator, urban environment, urban sustainability.

## 1. INTRODUCTION

In the context of an increasingly accentuated urbanization at the global level, the concept of urban sustainability represents an increasingly important element in the framework of sustainable development, which is already becoming an omnipresent paradigm for economic growth, environmental protection and social equity. Rapid urbanization is the one that places a strong emphasis on the need to obtain real results regarding the sustainability of cities [1]. It thus becomes important that cities and communities are effectively evaluated in terms of the progress made on the path to a more sustainable development. The problem of urban sustainability being an extremely current one, the sustainable development of the city has become an important topic even at the political level, being anchored in European treaties and being at the center of European politics.

In the framework of sustainable development, urban sustainability is associated with economic growth, social equity and environmental protection. For this reason, it is necessary to correctly evaluate the progress made by cities on the way to a more sustainable development.

Currently, there is a large number of indicators through which different aspects of urban sustainability are evaluated and the quality and equity of the urban environment are monitored.

It is known that for the assessment of urban sustainability, the aim is to ensure the prosperity and quality of urban life, and sustainability indicators allow the development of a new perspective on how urban areas contribute to the sustainability of the global environment.

## 2. Literature Review

At the level of 2015, the UN estimated that 54% of the global population lived in cities, which where considered, therefore, the main places of life in society [2]. By 2030, it is expected that 60% of the global population will be housed in cities, given that one person in three will live in cities with over half a million inhabitants [3]. Also, the United Nations [4, 5] predict a share of the urban inhabitants in the world population of 70% by the year 2050.

Although, historically speaking, the size of the cities indicates the wealth of countries, today many of the most densely populated cities are actually located in the poorest countries [2]. In the current, unprecedented expansion, over 90% of urban growth is registered in developing countries, and in the urban areas of the poorest regions of the world, approximately 70 million inhabitants are added annually [6, 7].

As the UN also stated in 2015, urban population growth can lead to economic and social development, without a negative impact on the environment, only through good planning and governance [8].

The analysis of the specialized literature identifies the fact that there is a large number of studies that highlight numerous indicators that evaluate different aspects of the sustainability of an urban system.

Tanguay et al. [9] analyzed 17 studies on the use of sustainable development indicators applied to western developed countries. The analysis reveals a lack of consensus both on the conceptual framework and on the selection and optimal number of indicators that can capture the progress registered in this direction.

Saum et al. [10] identified 2 indicators that are present in over 50% of the methodologies used in different studies, 11 indicators used in over a third of the methodologies and 34 indicators used in over 15% of the methodologies. Among the 34 urban sustainability indicators identified, the following can be listed: the employment rate compared to the unemployment rate, the area covered with green spaces, water consumption per inhabitant, air quality, income level, municipal waste generated, the population with higher education, the amount of emissions pollutants etc.

City dwellers perceive the progress made on the path to sustainable development by increasing their material well-being, improving the quality of the environment, public services and facilities offered with the best possible quality.

There is an unanimously accepted opinion that a city that fights to counteract climate change and that seeks to increase the quality of life of its citizens is a sustainable city. Sustainable cities, an objective of urban planners, are therefore a necessity in the fight against climate change.

There are numerous works in which the authors created prototypes of the City Sustainability Index. For example Mori et al. [11] created such a CSI prototype for 18 megacities, using 5 minimum indicators and 7 maximum indicators selected based on data availability and comparability of megacities, from world, national and municipal databases.

Researchers agree that sustainability depends equally on economic, social, environmental and governance factors [12]. In the detailed report: Indicators regarding sustainable cities, 12 environmental indicators for sustainable cities are presented, which cover categories regarding the sustainability of the urban environment and which aim to reduce the risks generated by climate change, adaptation to these changes, air quality, water, nature and biodiversity, sustainable land use, waste, energy performance, noise, sustainable urban mobility, ecological growth and eco-innovation as well as governance. In this report it is specified that there is a set of tools that make up the reference framework for sustainable cities (RFSC) and that support European cities to implement the SDGs of the Leipzig Charter on sustainable European cities. This reference framework for sustainable cities includes a number of 16 key indicators, as well as 300 additional indicators that cover aspects related to economy, society, environment and governance [12].

## 3. Methodology

In the present work, the sustainability assessment was carried out with the help of a composite indicator resulting from the assessment of the following 3 key areas: economic, environmental and social. Each key area was divided into several categories, each category comprising a number of indicators.

Tables 1, 2 and 3 contain the indicators selected and proposed by us for evaluating progress and comparing the 11 European states corresponding to each key field among the 3 mentioned. A very important criterion regarding the choice of indicators was the availability of indicator values in the case of the 11 countries at the level of the same year.

We selected the following 26 indicators, whose values for the 11 states can be found in Table 4: GDP/capita, annual inflation rate, unemployment rate, GINI coefficient, average gross salary, housing cost/total income, urban population/total population, total amount of waste generated, recycling rate of municipal waste, renewable energy/total energy consumed, GHGs emitted into the atmosphere, excellent bathing water condition/total water, population that does not own a personal car/total population, households with 3 and over 3 cars owned/total households, green space area in the country's capital/total area, cycling/total traffic volume, population connected to the wastewater treatment system/total population, population connected to the water distribution network/total population, premature deaths due to pollution of air/100,000 people, road deaths/1 million people, school dropout rate, number of doctors/100,000 patients, number of homicides, population owning less than one diploma/total population, net expenses with social protection/total expenses and fatal work accidents/100,000 employees.

The 26 indicators were grouped on the 3 key areas, as shown in Tables 1, 2 and 3 below:

**Tabel 1. Proposed indicators for the "Economic" field**

| Subdomain | Indicator | Description | Objective |
|---|---|---|---|
| Prices | Inflation rate [13] | Changing prices for goods and services (%), 2022 | ↓ |
| | Share of housing cost in total income [13] | Housing cost from disposable income/household (%), (2021) | ↓ |
| Income level | GDP/capita [13] | It is part of the set of sustainable development indicators, used to monitor progress towards achieving SDG 8, regarding decent work and economic growth (Euro/capita), 2021 | ↑ |
| | Average gross salary [13] | The average gross value of the salary (Euros/year), 2022 | ↑ |
| | GINI coefficient of equivalent disposable income [13] | Income or wealth inequality in a country, 2021 | ↓ |
| Population | Urban population [14] | Percentage of urban population in relation to the total population (%), 2021 | ↓ |
| | Unemployment rate [13] | Percentage of the total population that is unemployed (%), 2021 | ↓ |

**Tabel 2. Proposed indicators for the field "Environment"**

| Subdomain | Indicator | Description | Objective |
|---|---|---|---|
| Air quality | Greenhouse gases emitted [13] | Amount of $CO_2$, $NO_2$, $CH_4$, etc. in $CO_2$ equivalent emitted into the atmosphere (mil. tons), 2020 | ↓ |
| | Renewable energy from total energy consumed [13] | It is part of the set of sustainable development indicators of the EU, shows the percentage of renewable energy from the total energy consumed (%), 2020 | ↑ |

| | | | |
|---|---|---|---|
| Natural spaces | Green space in the capital city [15] | Total urban green space in the country's capital/urban area (%), 2022 | ↑ |
| | Condition of the bathing waters in excellent condition [15] | State of excellent quality bathing waters/total surface waters (%), 2021 | ↑ |
| Waste | Amount of waste/capita [13] | Total amount of waste generated (Kg/capita), 2020 | ↓ |
| | Municipal waste recycling rate [13] | The proportion between the amount of municipal waste recycled and the total amount of waste generated (%), 2021 | ↑ |
| Environmental impact | Percentage of population that does not own a personal car [16] | The proportion of the population that does not own a personal car from the total population (%), 2022 | ↑ |
| | Percentage of households with 3 or more cars/household [16] | Proportion of households owning 3 or more cars/household (%), 2022 | ↓ |
| | Cycling modal share [17, 18] | Share of cycling in the total volume of traffic (%), 2022 | ↑ |

**Tabel 3. Proposed indicators for the "Social" field**

| Subdomain | Indicator | Description | Objective |
|---|---|---|---|
| Social services | Population connected to wastewater system [13] | Percentage of population connected to the urban wastewater treatment system compared to the total population (%), 2020 | ↑ |
| | Population connected to public water network [13] | Percentage of population connected to the public water network compared to the total population (%), 2020 | ↑ |
| Impact on health | Number of premature deaths [15] | Premature deaths due to air pollution/100,000 people, 2021 | ↓ |
| | Number of road deaths [13] | Number of deaths/1 million inhabitants, 2020 | ↓ |
| | Number of doctors [13] | Number of doctors/100,000 patients, 2020 | ↑ |
| Education | School dropout rate[13] | Percentage of population aged 18-24 who left education and professional training system early (%), 2021 | ↓ |
| | Population that holds a maximum of a degree [13] | The population holding a maximum of one diploma/total population (%), 2021 | ↓ |
| Security | Net expenses with social protection [13] | Expenditures with social protection/total expenses (%), 2020 | ↑ |
| | Fatal work accidents [13] | Fatal accidents at work/100,000 employees (%), 2019 | ↓ |

| | | |
|---|---|---|
| Number of homicides [13] | Number of homicides recorded by the police, 2020 | ↓ |

**Tabel 4. The values of urban sustainability indicators for the states under analysis**

| I. | Romania (RO) | Hungary (HU) | Bulgaria (BG) | Czechia (CZ) | Poland (PL) | Lithuania (LT) | Latvia (LV) | Estonia (EE) | Slovakia (SK) | Slovenia (SI) | Croatia (HR) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 9610 | 13690 | 6950 | 18020 | 13760 | 14820 | 12970 | 16490 | 15920 | 21310 | 13500 |
| 2 | 14,1 | 25,0 | 14,3 | 16,8 | 15,3 | 20,0 | 20,7 | 17,5 | 15,0 | 10,8 | 12,7 |
| 3 | 5,6 | 4,1 | 5,3 | 2,8 | 3,4 | 7,1 | 7,6 | 6,2 | 6,8 | 4,8 | 7,6 |
| 4 | 34,3 | 27,6 | 39,7 | 24,8 | 26,8 | 35,4 | 35,7 | 30,6 | 20,9 | 23 | 29,2 |
| 5 | 1303 | 1296 | 852 | 1549 | 1418 | 1730 | 1379 | 1553 | 1212 | 1927 | 1377 |
| 6 | 17,0 | 12,5 | 31,6 | 19,3 | 17,9 | 11,6 | 15,2 | 14,2 | 14,0 | 14,7 | 16.0 |
| 7 | 54 | 72 | 76 | 74 | 60 | 68 | 68 | 69 | 54 | 55 | 58 |
| 8 | 7338 | 1648 | 16785 | 3598 | 4492 | 2396 | 1501 | 12171 | 2340 | 3576 | 1483 |
| 9 | 11,3 | 34,9 | 65,5 | 43,3 | 40,3 | 44,3 | 39,7 | 30,3 | 48,9 | 60,0 | 31,4 |
| 10 | 24,5 | 13,9 | 23,3 | 17,3 | 16,1 | 26,8 | 42,1 | 30,2 | 17,3 | 25,0 | 31,0 |
| 11 | 110,0 | 63,1 | 49,6 | 113,6 | 377,3 | 20,3 | 10,6 | 11,6 | 37,1 | 15,8 | 23,9 |
| 12 | 84,0 | 60,2 | 89,6 | 81,3 | 44,5 | 89,2 | 73,2 | 67,7 | 50,0 | 83,0 | 95,7 |
| 13 | 33 | 28 | 22 | 17 | 17 | 19 | 22 | 24 | 15 | 5 | 10 |
| 14 | 4 | 4 | 6 | 7 | 7 | 6 | 7 | 6 | 8 | 15 | 10 |
| 15 | 26 | 36 | 46 | 36 | 47 | 57 | 46 | 50 | 41 | 67 | 74 |
| 16 | 6,2 | 22 | 3,4 | 6,3 | 5 | 7 | 2 | 4,5 | 8 | 6,3 | 4.39 |
| 17 | 56,0 | 82,78 | 76,25 | 86,10 | 75,38 | 77,08 | 80,11 | 83,00 | 69,70 | 67,43 | 54,60 |
| 18 | 72,42 | 100 | 99,44 | 94,6 | 92,25 | 83,02 | 79 | 84,7 | 89,9 | 73 | 93,0 |
| 19 | 132 | 118 | 183 | 77 | 109 | 60 | 52 | 6 | 80 | 72 | 119 |
| 20 | 85 | 47 | 67 | 48 | 66 | 62 | 73 | 44 | 45 | 38 | 58 |
| 21 | 15,3 | 12,0 | 12,2 | 6,4 | 5,9 | 5,3 | 7,3 | 9,8 | 7,8 | 3,1 | 2,4 |
| 22 | 333 | 313,9 | 427,7 | 409,5 | 237,8 | 448,3 | 333,9 | 347,9 | 366,9 | 330,3 | 352,2 |
| 23 | 256 | 77 | 66 | 57 | 261 | 99 | 93 | 37 | 63 | 11 | 40 |
| 24 | 21,6 | 19,2 | 20,8 | 12,0 | 13,0 | 10,9 | 14,2 | 16,7 | 13,2 | 13,3 | 17,0 |
| 25 | 17,1 | 18,0 | 18,3 | 21,4 | 23,3 | 19,2 | 17,6 | 19,3 | 19,4 | 25,7 | 23,8 |
| 26 | 3,0 | 2,1 | 3,4 | 2,0 | 1,1 | 3,0 | 2,8 | 2,5 | 1,5 | 1,6 | 3,0 |

The reasoning behind the calculation of the composite indicator was based on the use of the AHP method to determine the coefficients of importance associated with each indicator. The Expert Choice program was used to calculate the importance coefficients.

A group of 3 experts analyzed each key domain, subdomain and group of indicators, to establish the relative importance of the subdomains, the groups of indicators in each subdomain, and the indicators in each group. To make the comparison, the scale for the intensity of importance developed by Saaty [19] was used.

With the Expert Choice program, the global values of the importance coefficients were determined: CIn = {CI1,CI2,……..,CIn}.

The next step was the construction of the decision matrix for the 26 indicators and the 11 states, having the form:

$A = (a_{ij})_{m*n}$, where: $1 \le i \le m$, $1 \le j \le n$, m = number of indicators, n = number of states.

The indicators being expressed in different measurement units, in order to be compared, their values were normalized, obtaining the standardized matrix with values in the range 0-1, according to the minimum and maximum rules.

The standardized matrix obtained has the following form:

$S = (s_{ij})_{m*n}$, where: $1 \le i \le m$, $1 \le j \le n$, m = number of indicators, n = number of states and $0 \le s_{ij} \le 1$.

By multiplying the matrix S with the vector of importance coefficients CI, the overall score for each state was obtained.

Following the application of the algorithm, a general score was obtained for each state, and the best evaluation corresponded to the state with the highest score.

Table 5 includes the hierarchical structure and the value of the importance coefficients on each level.

**Tabel 5. The structure of the hierarchy**

| Sustainability evaluation | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Economic (0,24) | | | Environment (0,62) | | | | Social (0,14) | | | |
| E1(0,26) | E2(0,63) | E3(0,11) | M1(0,49) | M2(0,18) | M3(0,24) | M4(0,09) | S1(0,15) | S2(0,27) | S3(0,51) | S4(0,07) |
| I1(0,83) | I3(0,57) | I6(0,25) | M8(0,25) | M10(0,75) | M12(0,75) | M14(0,60) | S17(0,25) | S19(0,24) | S22(0,75) | S24(0,57) |
| I2(0,17) | I4(0,29) | I7(0,75) | M9(0,75) | M11(0,25) | M13(0,25) | M15(0,28) | S18(0,75) | S20(0,14) | S23(0,25) | S25(0,14) |
| | I5(0,14) | | | | | M16(0,12) | | S21(0,62) | | S26(0,29) |

After performing the calculation, we obtained the following values of the composite index (IC) for the 11 states, according to table 6.

**Tabel 6. Composite index values**

| State | RO | HU | BG | CZ | PL | LT | LV | EE | SK | SI | HR |
|---|---|---|---|---|---|---|---|---|---|---|---|
| IC | 0,399 | 0,423 | 0,381 | 0,538 | 0,412 | 0,641 | 0,683 | 0,558 | 0,514 | 0,713 | 0,692 |
| Place in hierarchy | 10 | 8 | 11 | 6 | 9 | 4 | 3 | 5 | 7 | 1 | 2 |

## 4. Results and discussion

Following the research carried out, we found, first of all, that the EU is fully involved in maximizing progress in terms of sustainable urban development.

From the results of our study, we find that among the 11 countries that we analyzed, taking into consideration the selected indicators, Slovenia ranks first in the ranking, having the highest value of the composite index. This aspect is due to the best values recorded by this country, among all the 11 analyzed, at the level of the reference year, for the following indicators: annual inflation rate, GDP/capita, average gross salary, number of road deaths per 1 million inhabitants , the net expenses with social assistance and the number of homicides. This country also has the lowest percentage of people who do not own a personal car, but on the other hand the highest percentage of households that own three and more than three cars per household, aspects that do not represent a good step towards a sustainable urban development.

In second place is Croatia, with the best values of the indicators related to the total area of green space in relation to the area of the capital, the proportion of bathing waters in excellent condition compared to the total surface waters, the total amount of waste generated and the school dropout rate. However, Croatia records the worst values for the unemployment rate and the percentage of the population connected to the wastewater treatment system.

The third highest value of the composite index is recorded by Latvia, which has the best values for greenhouse gas emissions and the use of renewable energy, but the lowest values for the recycling rate of municipal waste and the share cycling mode in relation to the total volume of the traffic.

On the 4th place is Lithuania, with the best values for the share of the cost of housing in the disposable income per household, for the number of doctors per 100,000 patients and for the percentage of the population with at most one degree.

The 5th place is occupied by Estonia, which records the lowest number of premature deaths per 100,000 people caused by air pollution among all the analyzed states. In 6th place is the Czech Republic, which has the lowest unemployment rate and the highest percentage of the population connected to the wastewater network.

The 7th highest value of the composite index is recorded by Slovakia, where there is the lowest income inequality and the lowest percentage of urban population among all the analyzed countries.

Hungary is in 8th place, with the lowest percentage of households that own 3 and more than 3 personal cars, the largest population that uses bicycles and the largest share of the population that is connected to the public water distribution network. Hungary, however, has the highest inflation rate and uses renewable energy to the smallest extent.

The 9th place is occupied by Poland, which registers the lowest number of fatal accidents at work, per 100,000 employees, but on the other hand it emits the largest amount of greenhouse gases in the atmosphere, has the lowest percentage of bathing waters in excellent condition, the lowest number of doctors per 100,000 patients and the highest number of homicides.

Romania ranks 10th with the lowest municipal waste recycling rate, the lowest percentage of the population connected to the public water network, the lowest percentage of the population that has at most one diploma and allocates the smallest expenses for social assistance. Although Romania has the highest number of road deaths and the highest school dropout rate, it still has the lowest percentage of the population living in the urban environment compared to the total population, the lowest percentage of households that own 3 and more than 3 cars/household, but also the largest percentage of the population that does not own a personal car.

In the last place is Bulgaria, which records the highest cost of housing in the urban environment compared to the disposable income of the household and the highest number of fatal work accidents per 100,000 employees, the lowest value of GDP/capita and of average salary gross, the highest value of the GINI coefficient, of the amount of waste generated, of the urban population compared to the total population and of the number of premature deaths due to air pollution. However, the data show that Bulgaria has the highest recycling rate of municipal waste.

## 5. Conclusion and future work

In our research, we initially followed the testing and validation of the developed analysis tool (methodology and electronic application) for the largest cities in Romania, by collecting the relevant data based on which we were going to calculate the composite indicator and depending on the results we were going to recalibrate the component elements and the way of calculation so as to avoid obtaining outliers. However, due to the unavailability of data at the monitored level, it was not possible to test and validate the methodology at this level.

Thus, for testing the methodology, we chose 11 of the Eastern European countries for which we were able to obtain data for the indicators we selected, at the level of the same year, primarily from the statistical authority of the European Union - Eurostat, from other European statistical documents and not only.

The obtained results encourage us to expand our research, applying the presented methodology to the level of cities in Romania after the steps we will take to obtain the data we need from the municipalities. Thus, in the future, we aim to identify those indicators that best reflect the needs and objectives of cities in order to compare cities with each other and to offer decision makers proposals, ideas and solutions in the direction of achieving better urban sustainability.

We propose that in the next period we will capitalize on the developed methodology and submit it to the attention of several decision-makers at the level of the local administration in Romania. We also intend to expand the set of indicators, organizing more workshops with representatives of stakeholders in the area of urban planning and sustainability.

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